



Space Launch System

The Future of Exploration

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Space Launch System

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November 7, 2013



A Deeper Purpose, A Bolder Mission



“To reach for new heights...

and reveal the unknown so that what we do
and learn will benefit all humankind.”



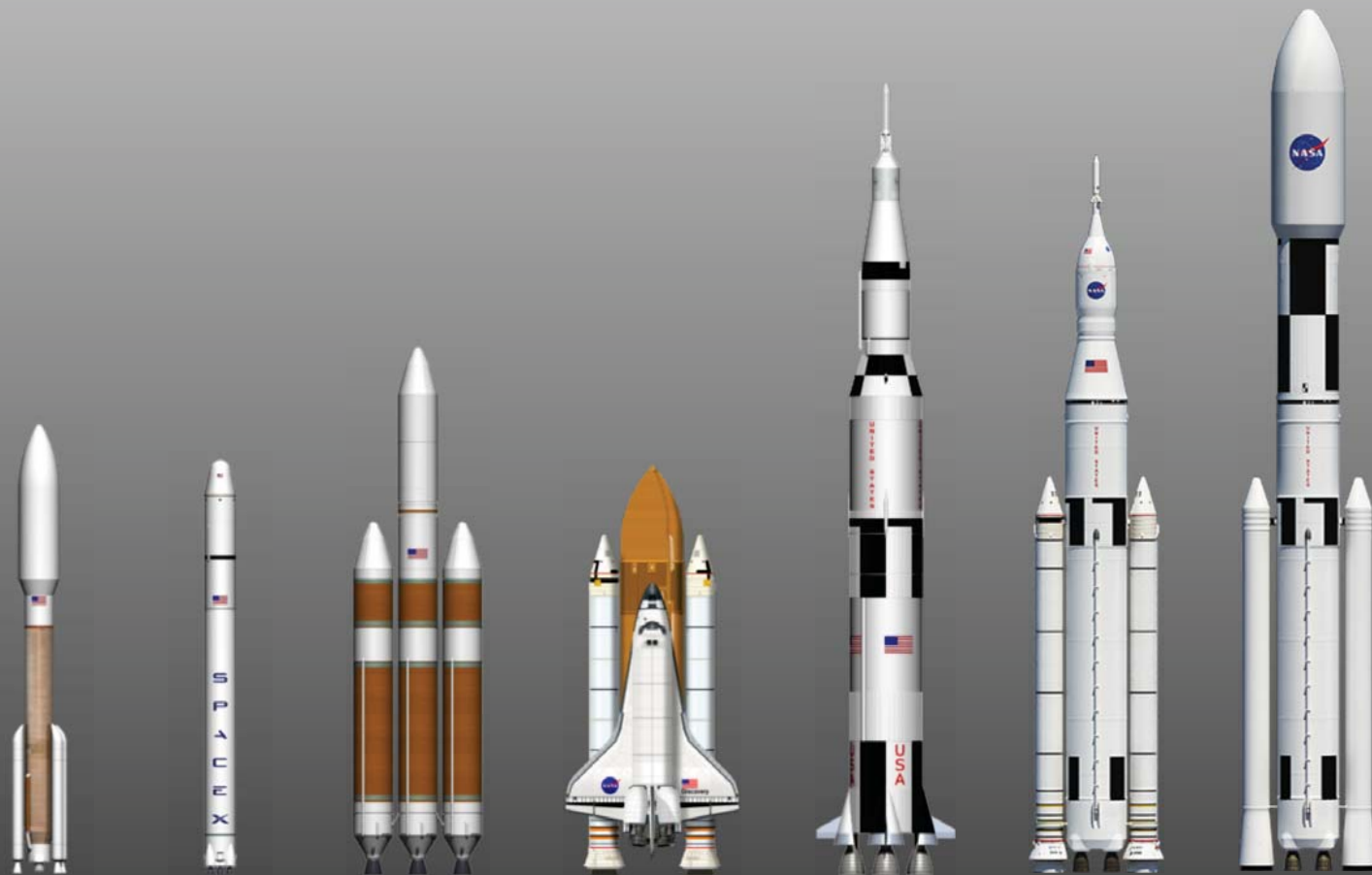
The Next Great Ship



Ships of exploration opened the paths
that became today's trade routes.



Bigger
Rocket =
Unrivaled
Mass,
Unrivaled
Volume



Enables missions
no other rocket can perform.



NASA's Space Launch System

Orion:

Carrying astronauts into
deep space

Core Stage:

Newly developed for SLS,
the Core Stage towers more
than 200 feet tall

RS-25 Engines:

16 Space Shuttle engines are
already in inventory



Interim Cryogenic Propulsion Stage:

Based on the Delta IV Heavy upper
stage; the power to leave Earth

Solid Rocket Boosters:

Built on Space Shuttle
hardware; more powerful for a
new era of exploration





NASA's Space Launch System



Launching Soon.
Building Today.



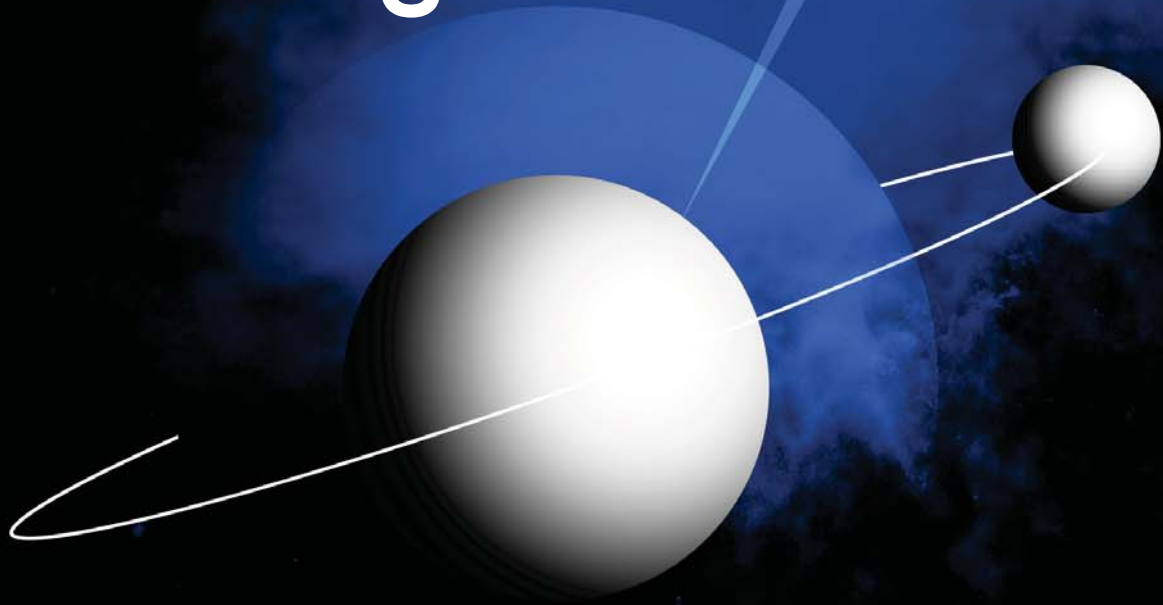
SLS is the first step in the **journey to Mars**



Going to Mars will be difficult.
SLS provides the power that it takes.



Space Launch System Core Stage



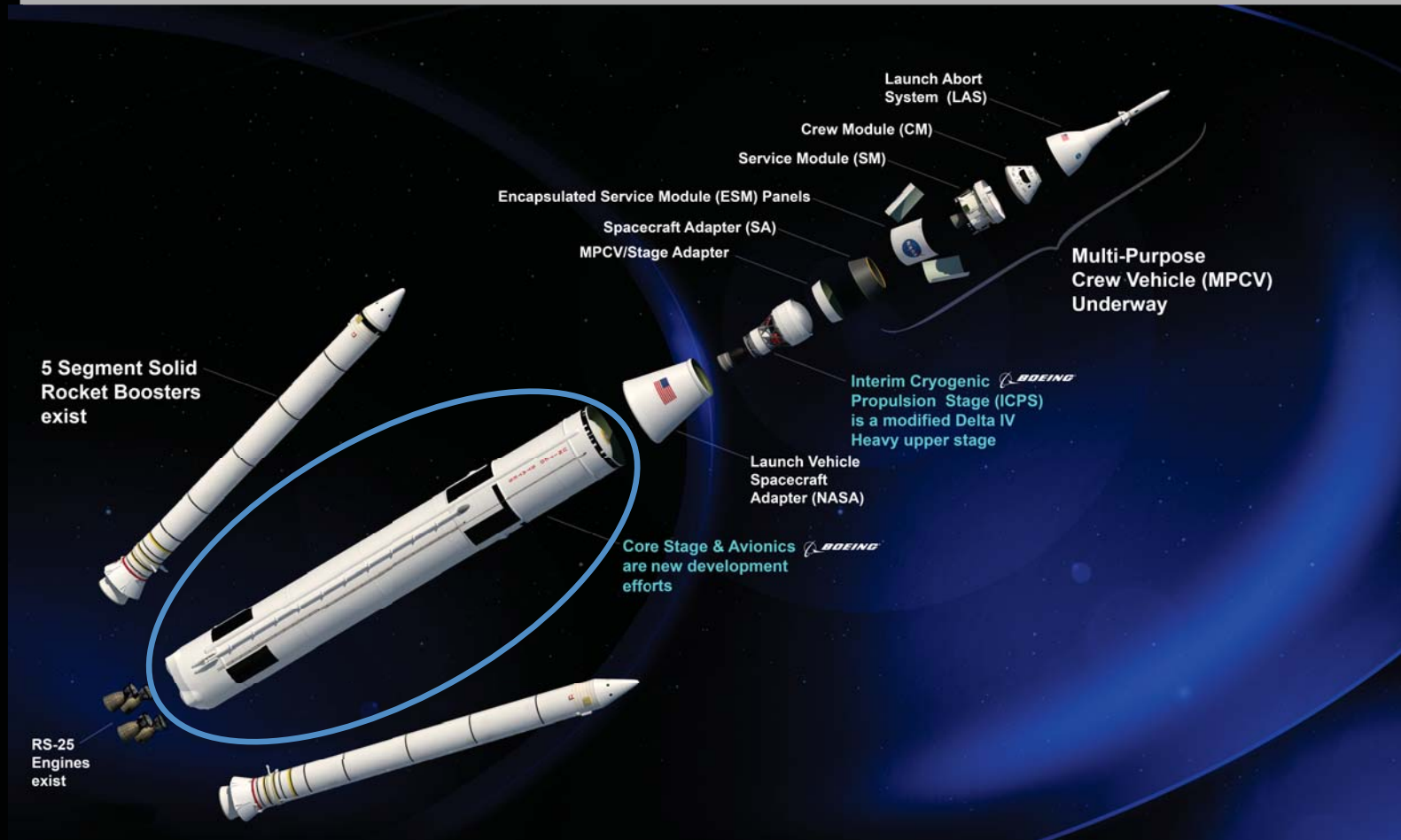
Michelle Taylor, SLS Engineer
Boeing Corporation

B.S., Electrical Engineering; M.S., Aerospace Engineering
University of Alabama

November 7, 2013



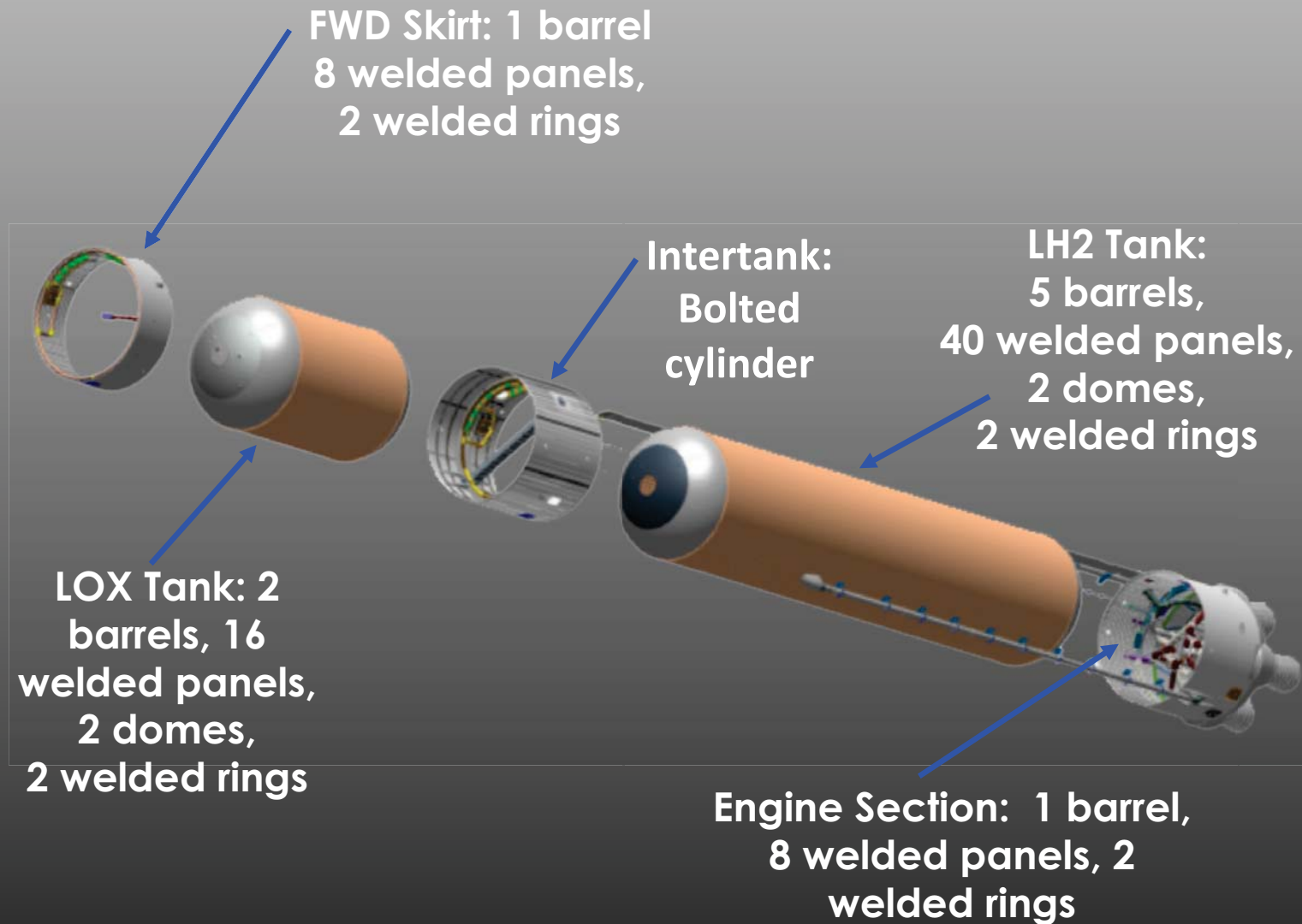
Core Stage & Avionics



NASA Marshall Space Flight Center (MSFC) Integrates SLS



Core Stage Major Structural Elements





Vertical Weld Center (VWC)



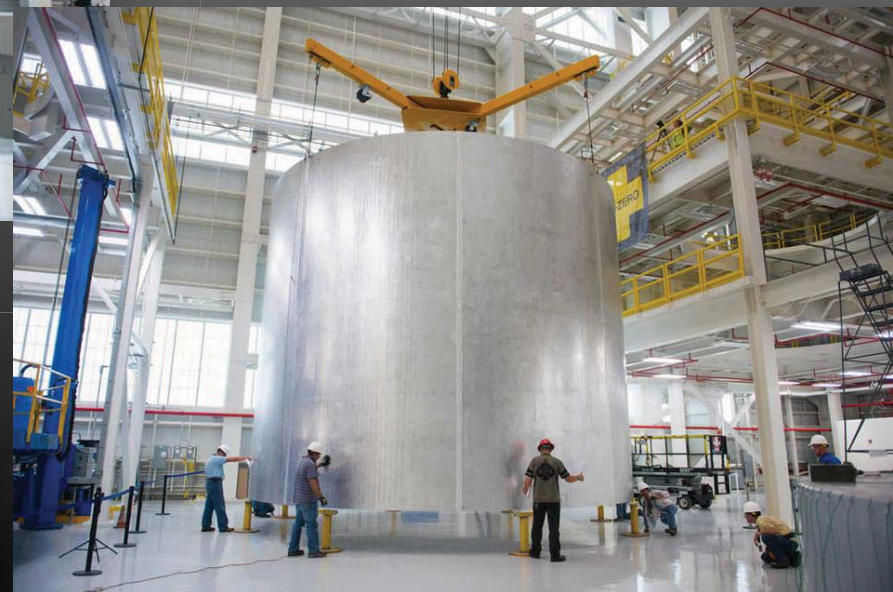
VWC Dimensions

- 41 feet tall
- 40 feet wide
- 50 feet long
- Weight –165.5 tons (not including production hardware)

VWC Complete - Tool In Use



First Tank Barrel at MAF Vertical Weld Center





Enhanced Robotic Weld Tool (ERWT)

- Welds twelve gore panels together to form gore section
- Welds dome cap to top and ring to bottom of gore section to create complete dome



- The Circumferential Dome Weld Tool (CDWT) welds gore dome assemblies, rings and dome caps together to make dome assemblies



Segmented Ring Tool (SRT)



- Welds six ring segments to form one 8.4 meter ring
- Y-Rings connect tanks domes and barrels
- L-Rings connect dry structure barrels



Space Launch System

Rocket Engine Technology

Mike Kynard, Manager
SLS Liquid Engines Element
NASA Marshall Space Flight Center

November 7, 2013



RS-25

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The Workhorse of SLS Core Stage



RS-25 Single Engine Test on A1 Test Stand at Stennis Space Center

<i>Core Stage Engine</i>	<i>Existing RS-25 Inventory</i>	<i>New Build RS-25</i>
Propellant	LO2/LH2	LO2/LH2
Max power level	109%	111%
Throttle Range	65%–109%	65%–111%
Avg Thrust @ max Pwr (vac)	512,185lbs	521,700lbs
Min Isp @ max Pwr (vac)	450.8 (452 Avg)	450.8
Engine Mass (each)	7,816	NTE 8,156
Nom, Range MR	6.043, 5.85-6.1	6.043, 5.85-6.1
Size	96" x 168"	96" x 168"

RS-25 as the Space Shuttle Main Engine

- 3171 Total Starts
- 1,095,679 Total Seconds
- 135 flights – 100% mission success
- Reusable – Designed for 55 starts and 27,000 seconds
- First Test – 1975, Last Flight – 2011



J-2X

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Upper Stage Engine for Evolved Vehicle



**Gimbal Test for J-2X
On A1 Test Stand at Stennis
Space Center**

<i>Upper Stage Engine</i>	<i>J-2X</i>
<i>Propellant</i>	LO2/LH2
<i>General Attributes</i>	
Max power level	100.0%
Thrust (vac)	294,000 lbf
Min Isp (vac)	448 seconds
Size	92" X 131"
Engine Mass	5,400 lbm
Mixture Ratio	5.5
Secondary Power Level	~82%

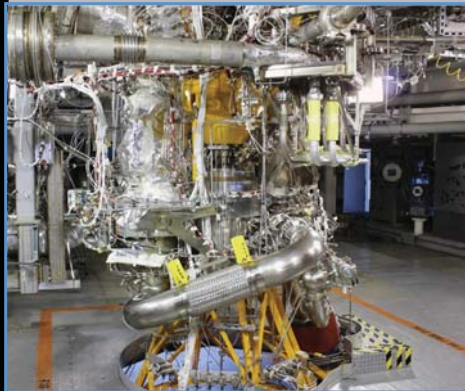
Key Baseline Features

- Short nozzle implemented (285k, 435s)
 - (Capable of 294K thrust and 448s)
- Re-startable



J-2X Development

- **System Testing**



Powerpack 2

- 13 tests
 - Performance characterization of turbopumps, inlet ducts, and turbine bypass system
- 6177 seconds total
 - Includes 1350 second test - longest test on A1 test stand



Engine 10001

- 21 tests
 - The first 10 tests performance characterization at sea level
 - Next 11 tests performance characterization with stub nozzle extension at simulated altitude
- 2718 seconds total



Engine 10002

- 6 tests on A2 test stand
 - Engine-to-engine performance repeatability characterization with stub nozzle at simulated altitude
- 7 tests on A1 test stand
 - Gimbal testing at sea level
- 5201 seconds total to date

14,096 total seconds



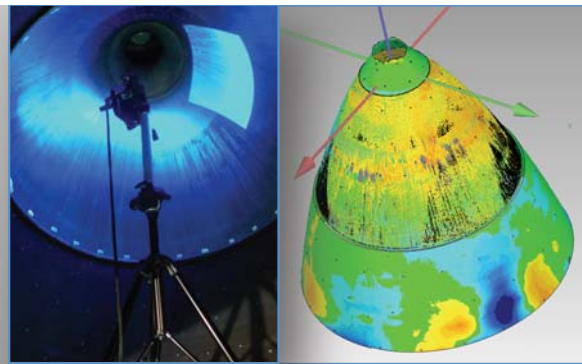
Single Engine Test Facility



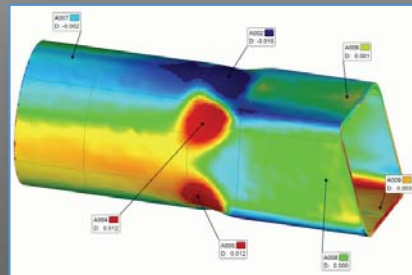


Technology We're Developing

- Structured Light Scanning Development



Replaced difficult measurements with scanning to help **reduce performance uncertainty** (throat and exit areas)

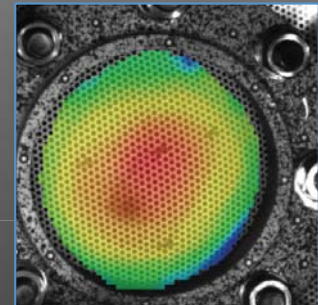


Structured Light Introduced to Sub-tier Vendors to modify tube dies to **integrate supply chain** (i.e. reduce turn around time for nozzle assembly)

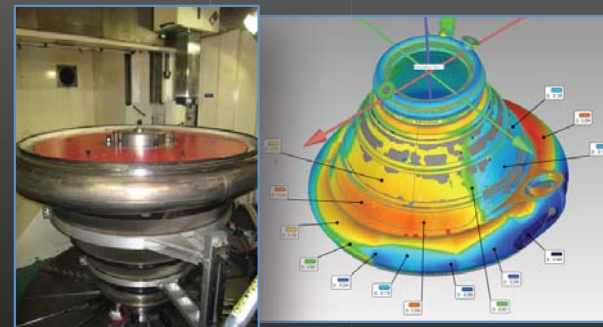
Training and Implementing as a new technique for Rocketdyne Personnel



Completing study to advance structured light as a quality acceptance tool. **Implementing > 5:1 time savings.**



Developing new optical techniques to augment traditional engine measurements



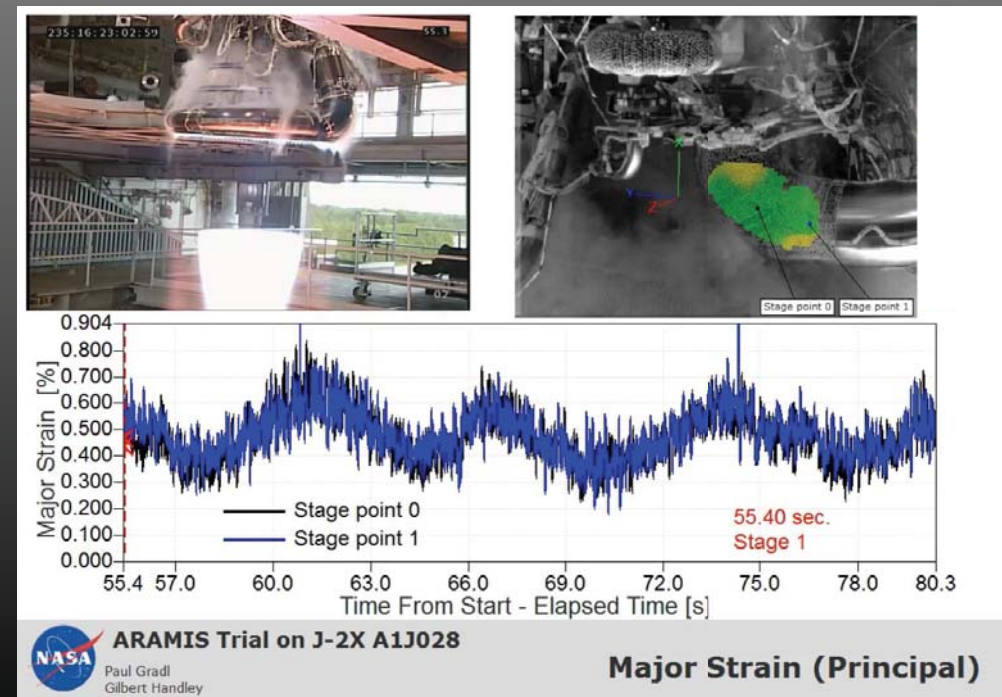
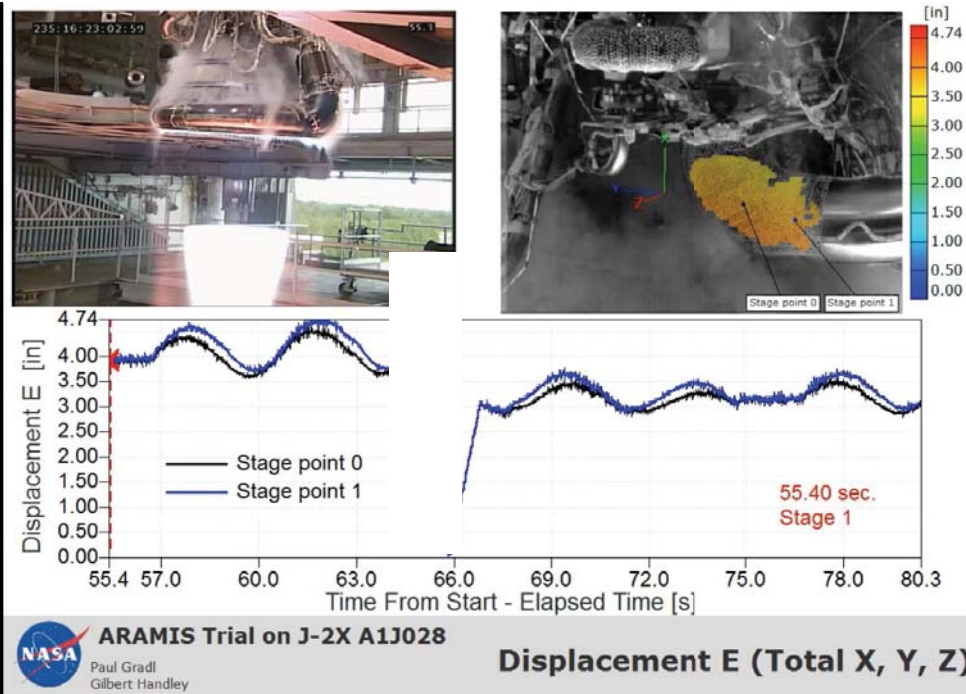
Structured Light Used to **Generate Machining Code** and Match Machine at PWR

Reducing the Development Cycle for Hardware



Technology We're Developing

- Structured
Light





Technology We're Developing

- **Selective
Laser
Melting**





Technology
We're
Developing

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**Selective
Laser
Melting**





Engine Controller Unit (ECU)

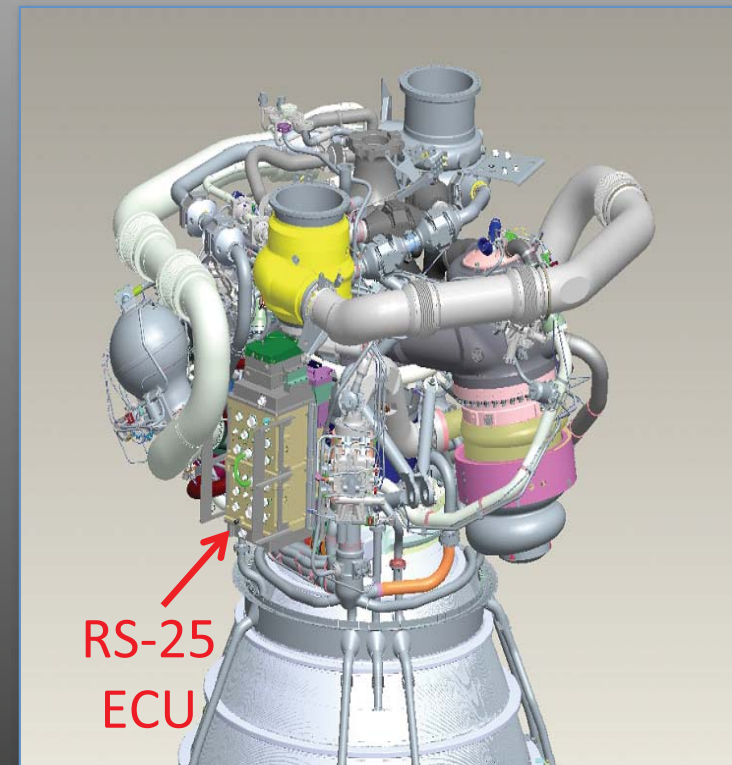
◆ ECU function

- Controls thrust and mixture ratio
 - Open and closed loop
- Continuously monitors engine health
- Provides electric power to control elements, sensors, and effectors
- Accepts commands from and reports data to vehicle computers

◆ **Challenge:** Heritage controller incompatible with new vehicle

◆ **Solutions**

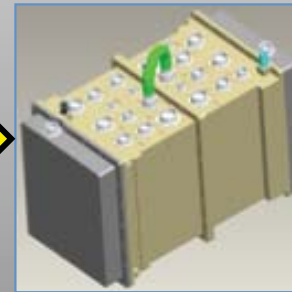
- Design new controller rather than adapt old
- Leverage J-2X design for “universal controller”





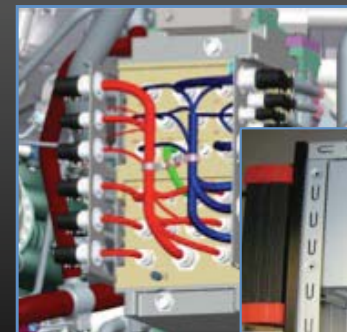
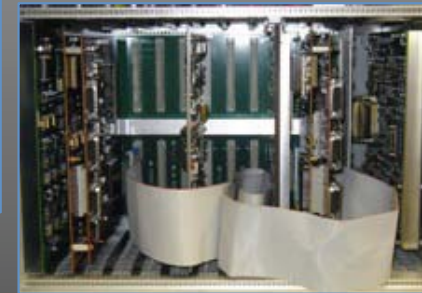
Engine Controller Unit (ECU) (Continued)

**SSME
Engine Controller Unit**



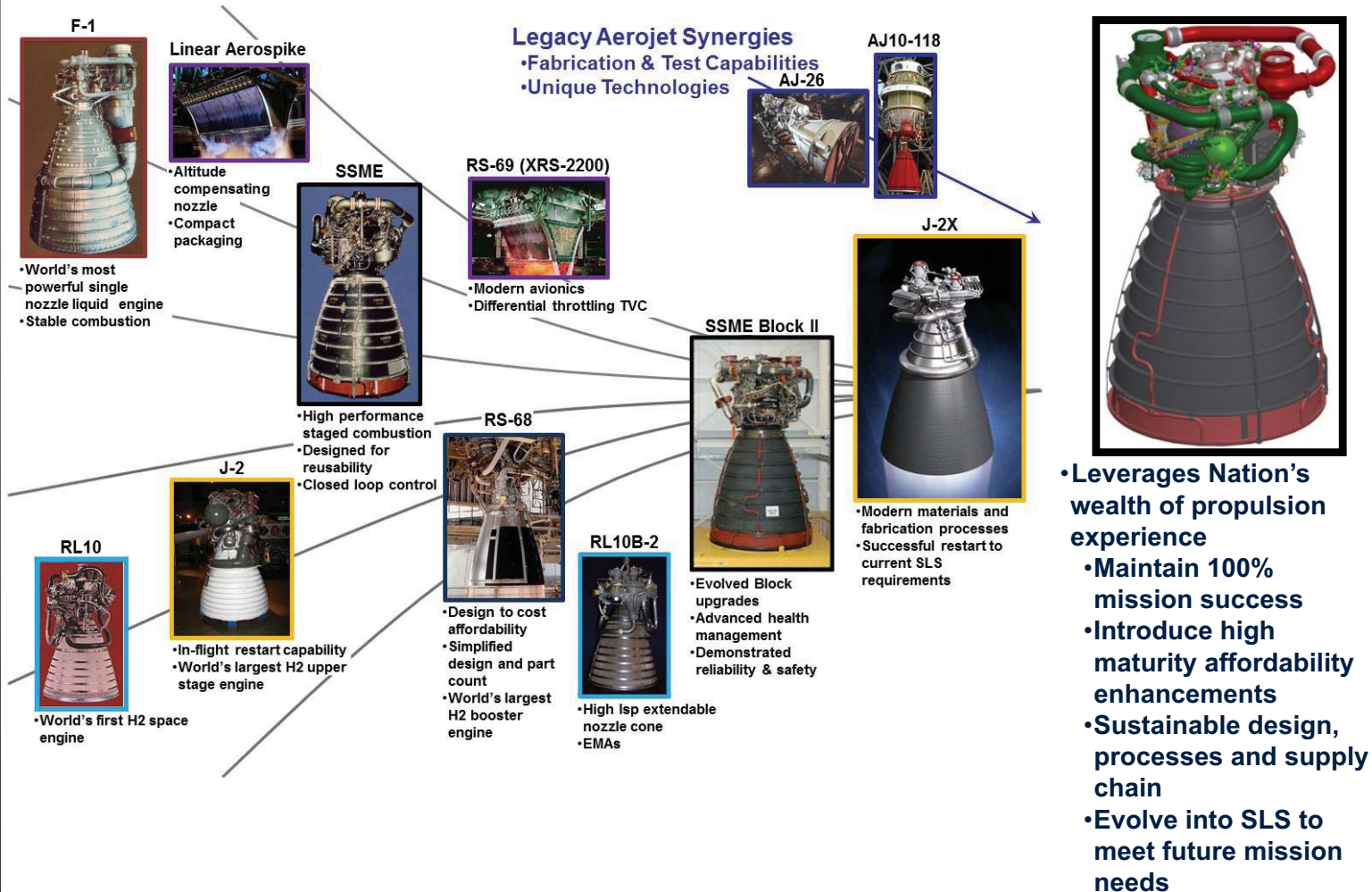
RS-25 ECU
Basic design supports
RS-25 and J-2X

**J-2X Engine Controller
Unit**





Roadmap to Improved RS-25



Delivery of affordable RS-25 engines is key to SLS success. J-2X represents the current state of NASA/AR capability to affordably design, develop, test, evaluate, and manage human-rated flight-qualified liquid rocket engines.



Space Launch System Systems Engineering & Integration

Garry Lyles, Chief Engineer
SLS Program Office

B.A. in Mechanical Engineering, University of Alabama
Class of 2010 Distinguished Engineering Fellows

November 7, 2013



"We're going to get this country — and the world —
exploring beyond low-Earth orbit very shortly."

— Dan Dumbacher
Deputy Associate Administrator
Exploration Mission Directorate

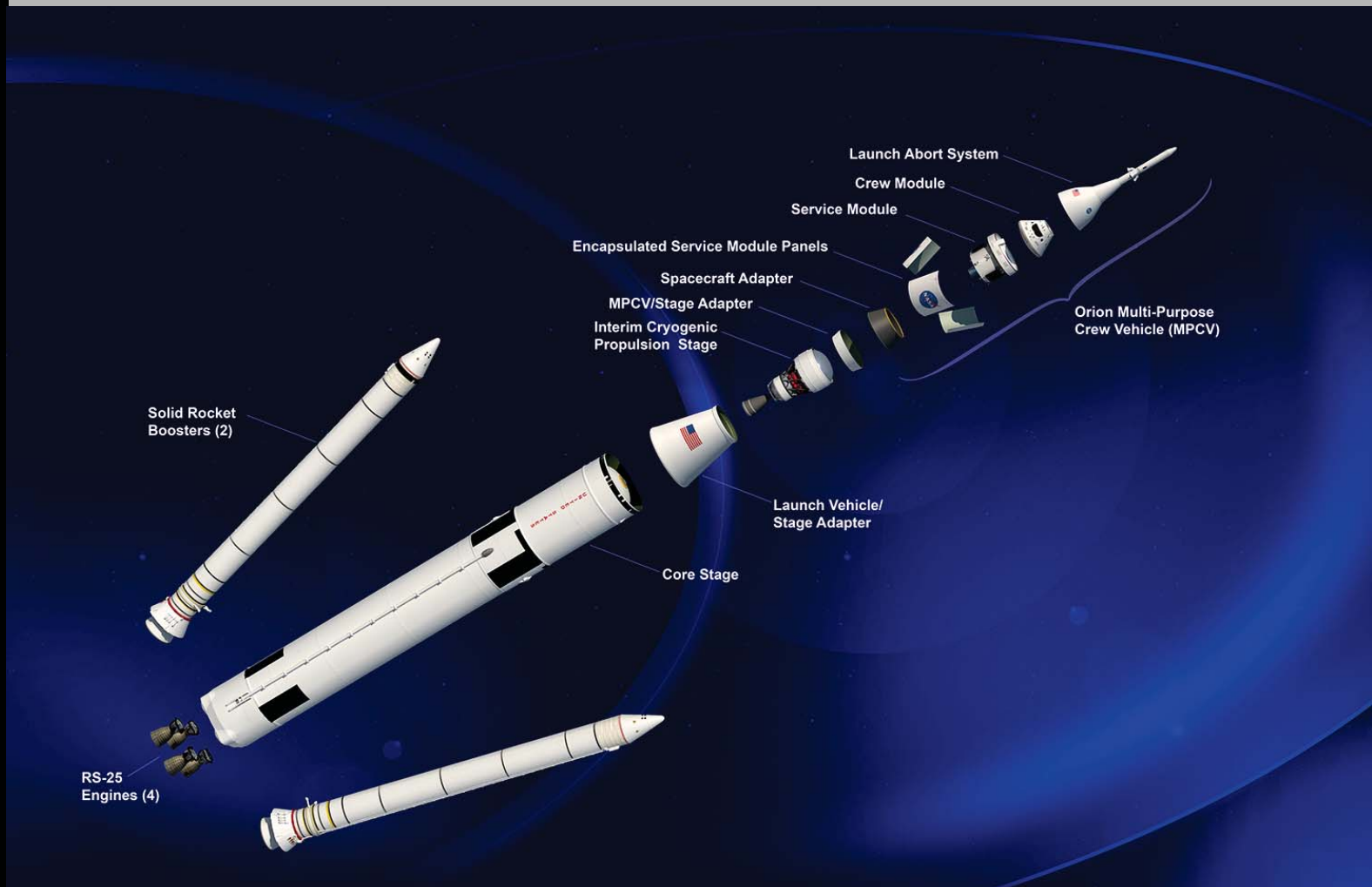
A National
Infrastructure
Asset



Exploration Mission 1



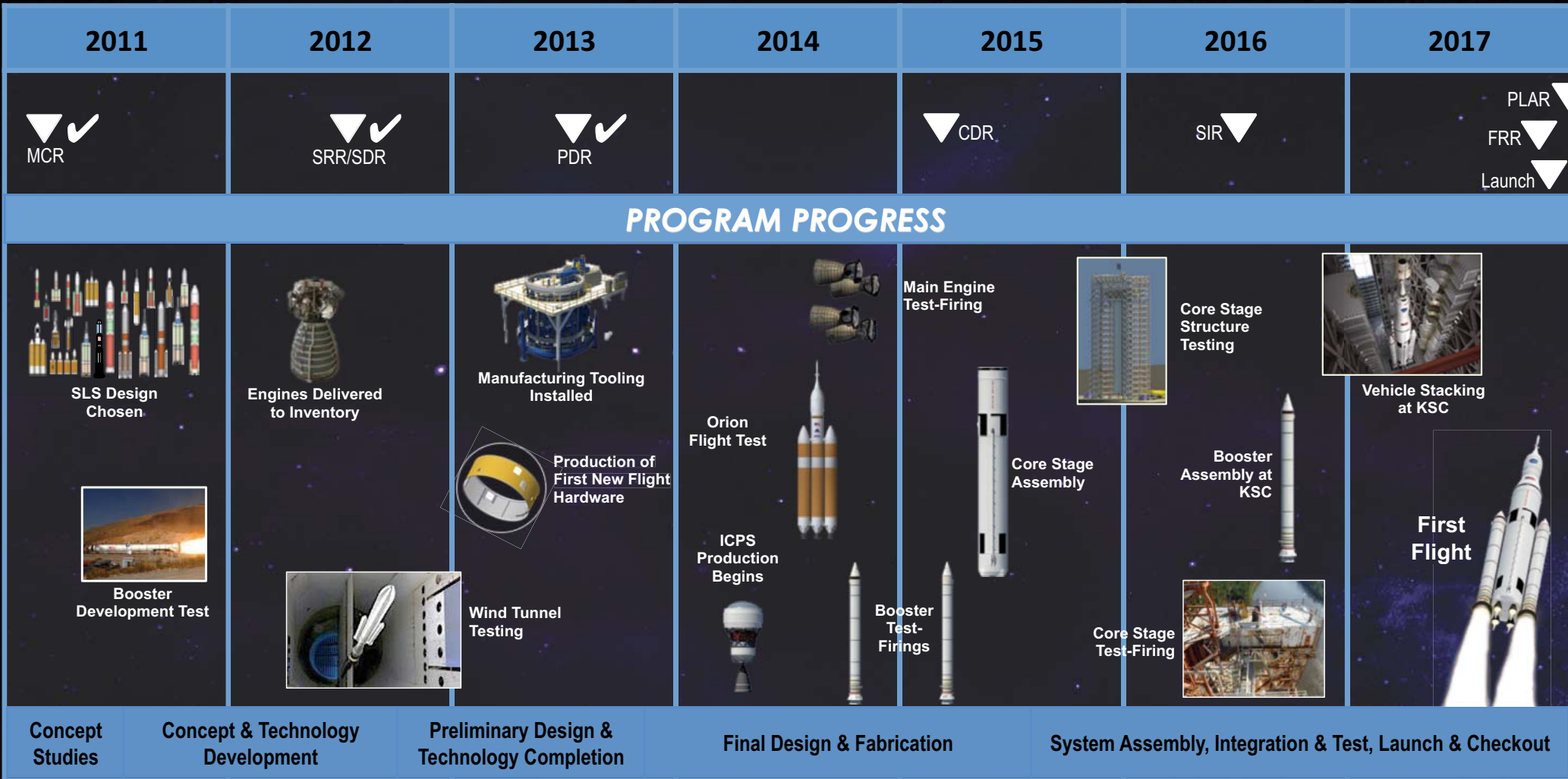
70 Metric Ton Expanded View



Initial Capability Builds on Heritage Hardware



SLS Development Schedule



MCR: Mission Concept Review

CDR: Critical Design Review

SRR: System Requirements Review

SIR: System Integration Review

SDR: System Definition Review

FRR: Flight Readiness Review

PDR: Preliminary Design Review

PLAR: Post-Launch Asses. Review



Communication and Integration

Accountability and Responsibility

Strong focus on leadership at all levels

Organized to balance functional expertise and cross-functional integration

Chief Safety Officer and staff provide guidance, analysis, and oversight/insight

Chief Engineer serves as lead designer, with staff focused on technical integration

Early integration of production considerations

Entire organization focused on stakeholder value

SLS Systems Engineering & Integration Organization	Systems Engineering	Vehicle Management	Structures & Environments	Propulsion	Production	Integrated Avionics & Software	Operations	Test	Safety & Mission Assurance
Program Chief Engineer (CE)	Lead Systems Engineer (LSE)	Discipline Lead Engineer (DLE)	DLE	DLE	DLE	DLE	DLE	DLE	Chief S&MA Officer (CSO)
Stages Element Chief Engineer (ECE)	Element LSE (ELSE)	Element DLE (EDLE)	EDLE	EDLE	EDLE	EDLE	EDLE	EDLE	Element CSO (ECSO)
Booster ECE	ELSE	EDLE	EDLE	EDLE	EDLE	EDLE	EDLE	EDLE	ECSO
Engines ECE	ELSE	EDLE	EDLE	EDLE	EDLE	EDLE	EDLE	EDLE	ECSO
Integrated Spacecraft & Payload ECE	ELSE	EDLE	EDLE	EDLE	EDLE	EDLE	EDLE	EDLE	ECSO
Advanced Development ECE									



Top Technical Issues

Loads and Environments

- ICPS Engine/Actuator Loads
- Predicted Core Stage acceleration
- Booster forward skirt
- MPCV designed to Ares loads
- Updated acoustic environments

Performance Threats

- Propulsion Performance
- Mass Growth
- Loads

Interfaces

- Core Stage Engine
- BSM Cover
- Core Stage
- Booster Separation
- Core Stage Engine
- FTS Pyro Delay

DAC-3 Touches Majority of Open Issues



Meeting Our Commitments & Exceeding Expectations

On Course for First Flight In 2017



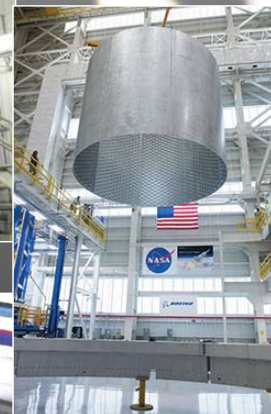
Engines
Tested
selective laser
melted part
on J-2X at
Stennis Space
Center
(March 2013)



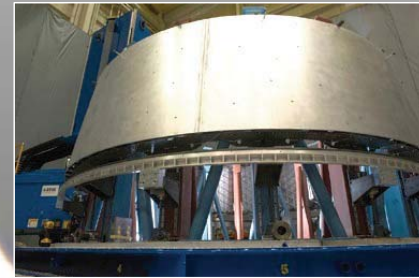
Boosters
Conducted
Thrust Vector
Flight Control
Test at ATK in
Promontory, UT
(Jan 2013)



Core Stage
Transferred
Core Stage test
panels to
Michoud
Assembly
Facility (MAF)
in New Orleans
(Spring 2013)



First Core Stage
barrel section
welded at MAF
(July 2013)



**Spacecraft & Payload
Integration**
Conducted fit-check
of the Multi-Purpose
Crew Vehicle Stage
Adapter at the
Marshall Space Flight
Center for 2014
Exploration Flight Test
(June 2013)



**Advanced
Development**
Conducted F-1
engine hot-fire
testing at Marshall
(Jan 2013)



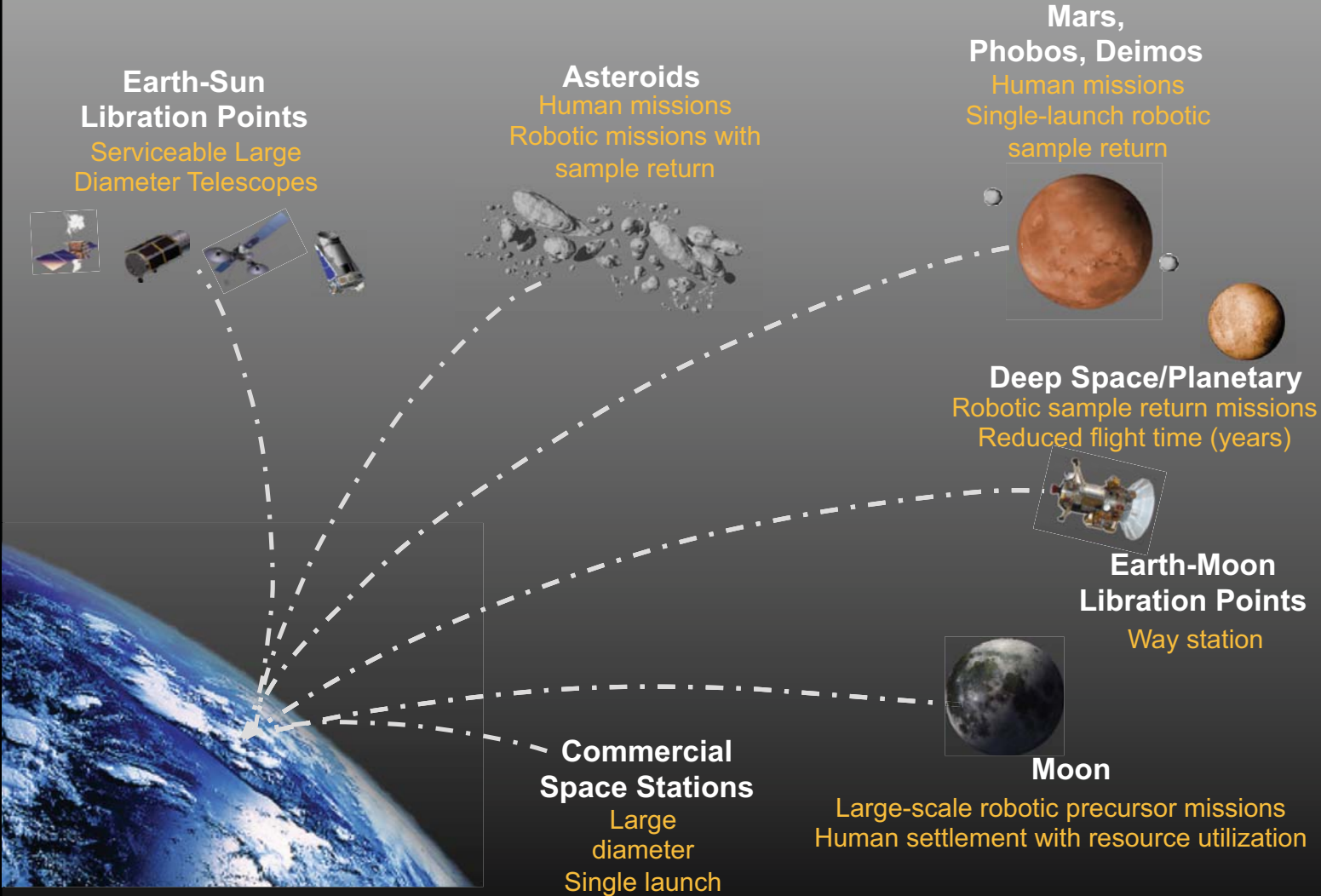
**Systems Engineering
& Integration**
Tested buffet model
in Langley Research
Center's Transonic
Dynamics Wind
Tunnel
(Jan 2013)

**"Awesome...huge step...stay focused and keep designing and
building. December 2017 is closer than we think."**

—William Gerstenmaier,
Human Exploration and Operations Director,
July 31, 2013



Islands in Our Ocean





Powering the Future of Exploration



**Aerospace Engineering
& Mechanics**

**Chemical & Biological
Engineering**

Computer Science

**Mechanical
Engineering**

**Civil, Construction & Environmental
Engineering**

**Electrical & Computer
Engineering**

**Metallurgical &
Materials Engineering**



“Man cannot discover
new oceans
unless he has the
courage to lose
sight of the shore.”

Join us on
the journey

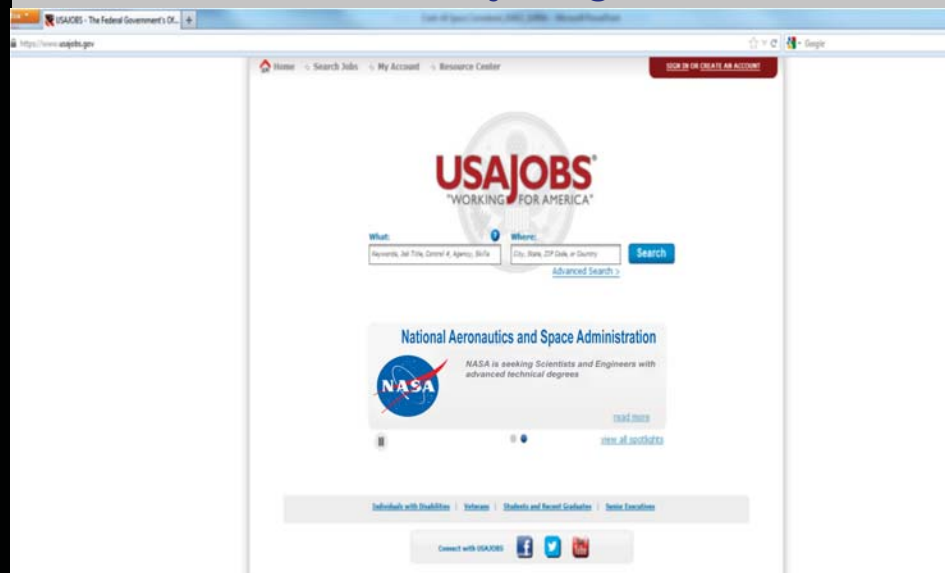
www.nasa.gov/sls
www.twitter.com/nasa_sls
www.facebook.com/nasasls



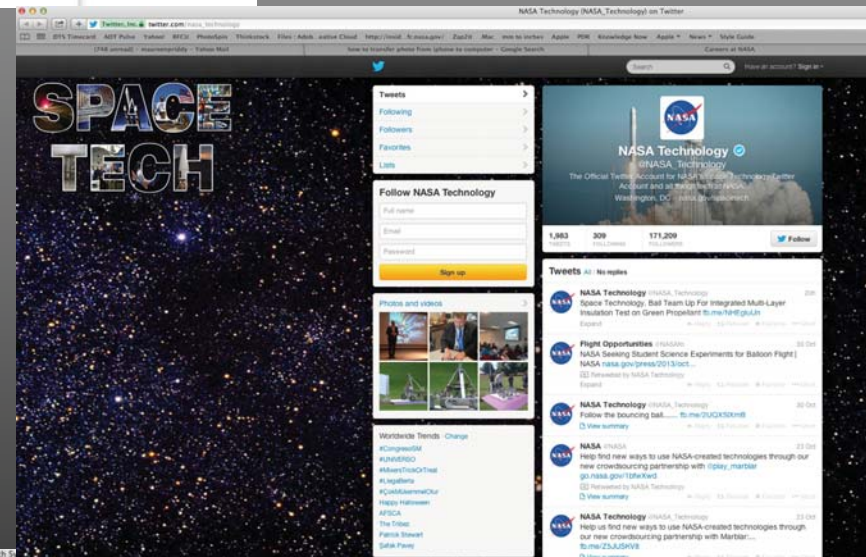


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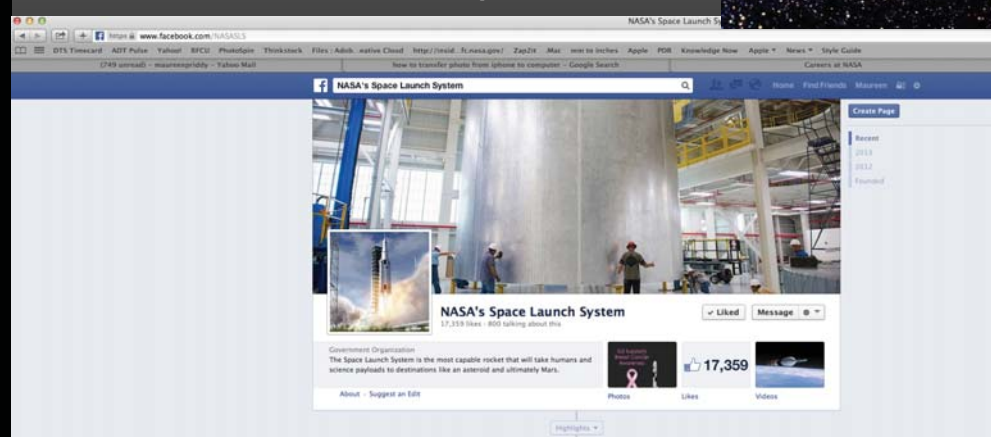
www.usajobs.gov



twitter.com/nasa_technology



www.facebook.com/NASASLS





www.usajobs.gov/studentopps/default.htm

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[PMF Program](#)
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[Pathways Opportunities](#)

NASA Workforce Map

[Click to Begin](#)

Pathways Programs at NASA

NASA Pathways Programs provide opportunities for students and recent graduates to be considered for Federal employment through:

- NASA Pathways Intern Employment Program (IEP)
- NASA Pathways Recent Graduates Program (RGP)
- NASA Pathways Presidential Management Fellows (PMF) Program



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NASA Pathways Programs Toolbox

NASA Pathways IEP

View info on the NASA Pathways Intern Employment Program (IEP) for current students and individuals in a qualifying educational program

NASA Pathways RGP

View info on the NASA Pathways Recent Graduates Program (RGP) for individuals who recently graduated

NASA Pathways PMF Program

View info on the NASA Pathways Presidential Management Fellows (PMF) Program for advanced degree candidates

Additional Information

View info on student employment, including occupations, benefits, and other useful sites

Student Opportunities

Opportunities for students and recent graduates

One Stop Shopping Initiative

View info on non-civil service student opportunities available through NASA's Office of Education

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OSSI One Stop Shopping Initiative NIFS

Recruiting NASA Interns, Fellows and Scholars

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What is OSSI?

OSSI is a NASA-wide system for the recruitment, application, selection and career development of undergraduate and graduate students primarily in science, technology, engineering and mathematics disciplines. Opportunities for students in other disciplines are available.



Key Features for Students

Students have the ability to search and apply for all types of NASA internship, fellowship, scholarship opportunities in one system. A single internship or fellowship application places students in the applicant pool for consideration by mentors for all NASA internships or fellowships.

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Calendar for Students

03/16/2013 - 05/31/2013

Submit Internship Application for
Fall 2013 Session

06/01/2013

Begin to receive offers for Fall 2013
Session

06/01/2013 - 10/24/2013

Submit Internship Application for
Spring 2014 Session

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Student Discovery

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Students](#)

Getting Started for Students

1. Register in OSSI by going to the 'Log in/Register' tab
2. Create an interest profile to specify your areas of interest;
3. Complete an application;
4. Search and select opportunities of interest, identifying your top 15 prior to the end of the application period.



Questions & Answers